National Park Service
U.S. Department of the Interior

Interpretive Development Program
Climate Change Response Program

Interpreting Climate Change

Module 2 – Learning Companion
Knowledge of the Resource Issue

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Introduction

Some of the aspects of interpreting climate change that can seem the most daunting involve getting a grasp on the vast amount of ever-changing information on the topic—from the global to the local scale—keeping that information up to date, and then explaining the often complex scientific and historical information to peers and the public in a way that they can understand and that has relevance to them. This module of the curriculum contains information, suggestions, examples and resources that will make success in these on-going tasks easier and more realistic for interpreters. Acquiring knowledge of climate change does not have to be an intimidating task and there are many helpful resources.

Materials in this module include a section on the scientific method and science literacy, which form the critical foundation for the following section on climate science literacy and understanding the principles behind climate change. In addition, a section on the historical and cultural context of climate change is also included. Interpreters need to learn about historical events and cultural influences and attitudes that can be used to provide a human connection between their site and climate change. Finally, because parks provide strong tangible examples of climate change effects on landscapes and resources, which can be used to create relevant connections with park visitors, a helpful discussion of how to identify site-specific climate change issues and stories is presented.

Science Literacy for Interpreters

"Science, mathematics, and technology have a profound impact on our individual lives and our culture. They play a role in almost all human endeavors, and they affect how we relate to one another and the world around us. . . . Science Literacy enables us to make sense of real-world phenomena, informs our personal and social decisions, and serves as a foundation for a lifetime of learning."

—American Association for the Advancement of Science, Atlas of Science Literacy, Volume 2, Project 2061

The mission of the NPS is grounded in science. It is the interpreter's responsibility to professionally represent this science and to fulfill our mission in a way that is engaging, inspiring and educational. As such, interpreters must have sufficient knowledge of science to enable them to play a role in increasing science literacy among fellow staff and the general public.

Science literacy is the understanding of scientific concepts and methods that enable people to question the world around them and to evaluate or explain natural phenomena. People conversant in science can understand popular articles about science, engage in informed social discourse on scientific matters, and arrive at opinions based on facts and evidence. Not only is science literacy essential to an interpreter's ability to understand and communicate climate science clearly, but a discussion of the scientific method may be necessary to dispel misconceptions about climate change that are based on a lack of understanding of the scientific process. Such clarification may be instrumental in eliminating preconceived notions on both sides of the issue and in explaining the causes and effects of climate-induced changes in our national parks.

The Rules of Science

Edward O. Wilson describes science as "the organized, systematic enterprise that gathers knowledge about the world and condenses the knowledge into testable laws and principles." Science is but one way of learning about the world—traditional knowledge, emotional experience, and matters of faith are other methods. However, the power of science to predict outcomes, guide actions, and lay a transparent common foundation of reason makes science the NPS method of choice for making management decisions. Science is objective rather than subjective, so that conclusions should not be dependent on the personality of the individual making them.

The scientific method or process can be applied to a single experiment, but it also governs the arc of scientific knowledge spanning centuries. Science starts with curiosity— the identification of a question. The question may arise from a personal subjective opinion, an anecdotal story, traditional knowledge, or hard facts. The questioner then seeks evidence to formulate a hypothesis. A hypothesis is an educated guess that can be tested through further observation or experimentation. Through repeated testing or observation, the hypothesis may be disproven, or it may become generally accepted. If the latter, it may become a theory, though usually a theory encompasses more than one generally accepted hypothesis.

Theories are perpetually "on probation"; future evidence may cause a theory to be modified or occasionally disproven. Nearly the entire body of scientific knowledge is comprised of well-studied theories, most of which have withstood critical skepticism from numerous scientists.

Laws are unlike hypotheses or theories. Laws are a description of a set of observations with no exception. Unlike a theory, they do not explain the question of "why." Newton's law of gravity tells you how an object will fall, but not why it will fall. Several competing theories of gravitation attempt to explain why gravity exists; not all of them can be valid, but gravity is no less real. Care should be taken to avoid giving the erroneous impression that laws are the highest hierarchy of the three, as in "hypotheses, theories, and laws."

Finally, good science requires transparency. Scientists document their methods, record their results, and carefully step toward their conclusions. This allows other scientists to critique their work, assess their objectivity, and to potentially offer better explanations. Through this peer-review and publication process, the fittest theories survive. These theories then become the building blocks for future work.

Uncertainty in Science

Uncertainty is a normal part of the scientific process. It is important to appropriately frame uncertainty in scientific discourse. It would be a tragic error to dismiss research with some uncertainty as untrue. Waiting until "the science is certain" may be difficult, as even well-trusted theories can have lingering uncertainty after decades.

A series of documents titled, ***NPS Climate Change Talking Points*** categorize current research findings into three levels of certainty— what scientists are reasonably certain about, what scientists think is likely, and what scientists think is possible in regard to climate change. These broad categories are useful for guiding management actions and managing the risks of action. When managers encounter a high level of uncertainty in science, studies can still be taken into account, and actions can be taken that provide the least amount of risk to the resource.

Evaluating Scientific Conclusions

It is valuable for interpreters to understand the process scientists use when reviewing and evaluating scientific conclusions, even if they may not participate in the process. A solid understanding of this step can assist interpreters in communicating the rigor of science to the public and help in explaining the scientific definitions of "skepticism," "bias," and "uncertainty," three terms that mean very different things to scientists than they do to non-scientists.

- Question sources: All conclusions and interpreted material should be considered with healthy skepticism.
    - What question(s) does the researcher ask?
    - What hypothesis, thesis, explanation, or interpretation is being presented?
    - What methodology is being used?
    - Is the evidence accurate, credible, relevant, authentic, and comprehensive?
    - Are the conclusions reliable, verifiable, repeatable, and comprehensive?
    - How does the view presented fit with or challenge predominantly accepted theory and explanation?
- Recognize change: A full performance interpreter recognizes that scientific and historical explanations change as technology, analysis, methodology, and culture evolves. A full performance interpreter must be familiar with:
    - The evolution of perspectives about a given topic related to their site.
    - Competing and conflicting perspectives about a given topic.
- Identify bias: Culture, experience, interpretation, funding sources, ideologies, and underlying agendas of authors influence research.
    - Identify the purpose of the author(s) and sponsor(s).
        - Is there a profit motive?
        - Is there an ideological motive?
        - Is there a long-standing "official" position that the research might support or challenge? Is there a liability motive?
    - Is a special interest involved?
    - Have paid experts been used?
        - Check with other subject-matter experts to understand what biases may be present.
- Identify methodologies used: Different methods of investigation and schools of interpretation and analysis may lead researchers to different conclusions about the same topic.
- Identify uncertainties: Incomplete information or data can result in different conclusions.
- Identify base assumptions: Investigations of the same subject based on different assumptions can result in different conclusions.

Discussing the Scientific Process with Visitors

Interpreters may encounter situations when it becomes apparent that an individual or group does not fully understand the scientific process or how scientists work. Listed below are two common visitor cues that may suggest a dialogue about the scientific process is appropriate. (Additional examples and appropriate responses are also found at the **Skeptical Science web site**.)

- "It's just a theory." This is a common misconception about science and demonstrates the danger of using scientific jargon without properly explaining the context of the words being used. This statement may suggest that the visitor misunderstands or is unaware that science defines a "theory" much differently than the common usage of the term implies.
- "The scientists are just guessing. How can anyone predict the future?" A statement like this implies that the individual is unaware of the rigorous process of modeling and experimentation that scientists use to reach their conclusions.

Terms that have different meanings for scientists and the public

Scientific term	Public meaning	Better choice
enhance	improve	intensify, increase
aerosol	spray can	tiny atmospheric particle
positive trend	good trend	upward trend
positive feedback	good response, praise	vicious cycle, self-reinforcing cycle
theory	hunch, speculation	scientific understanding
uncertainty	ignorance	range
error	mistake, wrong, incorrect	difference from exact true number
bias	distortion, political motive	offset from an observation
sign	indication, astrological sign	plus or minus sign
values	ethics, monetary value	numbers, quantity
manipulation	illicit tampering	scientific data processing
scheme	devious plot	systematic plan
anomaly	abnormal occurrence	change from long-term average

Some commonly misunderstood scientific terms related to climate change science are listed in the table above. The entire article is a useful look at effective climate change communication strategies and can be read at: **Somerville & Hassol (2011)**. To delve deeper into science literacy see **Appendix I** listed at the end of this document.

Climate Science Literacy

Climate science literacy is an extension of science literacy that relates to understanding the processes that control the Earth's climate, and the scientific methods used to study these processes. People who are climate science literate know that climate science can inform decisions on how to adapt to, and to mitigate the effects of climate change. They have a basic understanding of the climate system, including the natural- and human-caused factors that affect it. Climate science literate individuals understand how climate observations and records as well as computer modeling contribute to scientific knowledge about climate. They are aware of the fundamental relationship between climate and human life and the many ways in which climate plays a role in human health. They have the ability to assess the validity of scientific arguments about climate and to use that information to support their decisions.

Why Climate Literacy Matters

Climate science literacy allows an understanding of an individual's influence on climate and climate's influence on individuals and society. Climate science literate people:

- Understand the essential principles of Earth's climate system,
- Know how to assess scientifically credible information about climate,
- Understand the potential human impacts of climate changes in their own communities and in the broader world,
- Communicate about climate and climate change in a meaningful way, and
- Are able to make informed and responsible decisions with regard to actions that may affect climate.

The interpreter's role is to engage visitors on climate change issues as they relate to specific resources at their site, and through establishing personal connections to the meanings and relevance of climate change to the site and visitor experience, provide opportunities for improved climate literacy. Listed below are some themes that may be used to facilitate better climate literacy among the general public.

- Scientific observations and climate model results indicate that human activities are now the primary cause of most of the ongoing increase in Earth's globally averaged surface temperature. If humans are the primary cause, we are also the primary solution.
- Climate change will bring economic and environmental challenges as well as opportunities, and citizens who have an understanding of climate science will be better prepared to respond to both.
- Society needs citizens who understand the climate system and know how to apply that knowledge in their careers and in their engagement as active members of their communities.
- Climate change will continue to be a significant element of public discourse. Understanding the essential principles of climate science will enable all people to assess news stories and contribute to everyday conversations as informed citizens.
- Climate change will affect the places that people care about, such as parks and the resources within them.
- Climate change will affect people, their communities, their ways of life, and their cultures. It will reshape food sources, economies, and material culture, among other factors. In turn, it will affect their priorities, beliefs, etc.

The Principles of Climate Science

Two recommended documents can be used by interpreters to develop a foundational understanding of climate change science. Available on the NOAA website, a 2009 document titled ***Climate Literacy: The Essential Principles of Climate Sciences*** identifies seven essential principles of climate sciences and provides a foundational background for each:

1. The Sun is the primary source of energy for Earth's climate system.
2. Climate is regulated by complex interactions among components of the Earth system.
3. Life on Earth depends on, is shaped by, and affects climate.
4. Climate varies over space and time through both natural and man-made processes.
5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
6. Human activities are impacting the climate system.
7. Climate change will have consequences for the Earth system and human lives.

A second document published by the National Research Council in 2012 titled ***Climate Change: Evidence, Impacts and Choices*** goes a little deeper into the subject and provides easily understandable information on how scientists know that climate change is happening and that it is human caused, and how predictions of future climate and its consequences are made. This document also has a useful section on choices that can be made to mitigate and adapt to climate change effects. Important climate topics included in this document include the following:

- Global temperature monitoring
- Greenhouse gas mechanism
- Global carbon cycle
- Keeling curve and greenhouse gas monitoring
- Identifying anthropogenic greenhouse gas components
- Global temperature forcing agents
- Long and short-term temperature variability
- Other effects including sea level rise and ocean acidification
- Climate modeling – forecasting and backcasting
- Emissions scenarios
- Predicted changes in temperature, precipitation, snow and ice, wildfires, etc.

The two documents above can help provide a useful climate science foundation for all interpreters presenting climate change programs. Also highly recommended is the self-study tutorial ***Climate Change: Fitting the Pieces Together***, developed by the University Corporation for Atmospheric Research's (UCAR) MetEd and provides a helpful and foundational overview of climate science.

Local Resource Impacts and Responses

A key component of climate change knowledge for interpreters is a thorough understanding of local resource impacts, both current and potential, along with knowledge of the park's strategies and actions for mitigation and adaptation. The NPS is in a unique position because parks provide a place where ongoing climate change effects can be seen and studied, and can then be understood and appreciated in a broader regional and global context. In addition, interpreters can help visitors understand how site-specific impacts relate to the visitor experience now and in the future. Parks are also places where visitors can see examples of proactive stewardship and sustainability underway.

See **Appendix II** at the end of this document for a general overview of climate change impacts in national parks. In addition, the ***NPS Climate Change Talking Point documents***, referenced earlier, are organized around eleven bioregions highlighting NPS specific resource impacts in each bioregion. See **Appendix III** for a brief overview of monitoring approaches that parks may engage in to study climate change within their landscape.

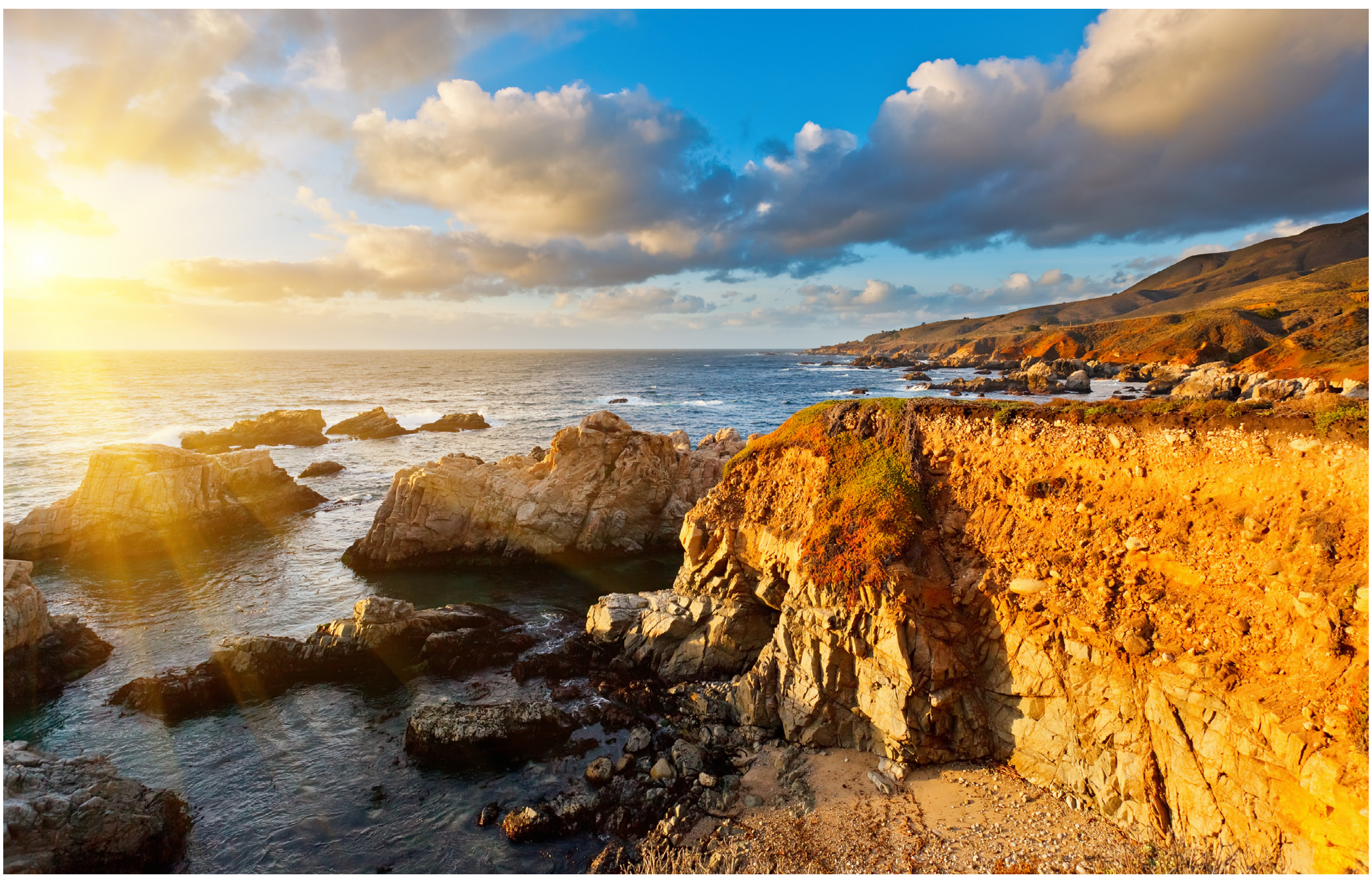
Staying Current with the Best Available Climate Science

Staying climate science literate does not require interpreters to sort through vast volumes of existing literature in order to keep up-to-date with all the new climate science information published on an almost daily basis. Instead, by periodically visiting key websites like the ***International Panel on Climate Change*** and ***U.S. Global Change Research Program*** sites, interpreters can get a synthesis of new information and stay up to date with the latest research on global or regional science.

It is important to stay current, however, not only to be aware of the latest science, but also to be knowledgeable of multiple explanations, theories, and interpretations, which may complement and/or conflict with each other. This breadth of knowledge allows interpreters to present balanced representations of the state of the science and to provide a range of perspectives on climate change and its impacts. By periodically visiting key websites like **Skeptical Science** and **Real Climate**, interpreters can stay up to date with the national discourse on this topic.

Scanning for newspaper articles, reading science magazines and newsletters and visiting other climate change oriented websites and blogs can also help interpreters stay current on global climate change issues. Keeping tabs on these information sources may lead to peer-reviewed publications that offer more in-depth and accurate information.

To stay current on more local climate change issues, interpreters should find a liaison within their park resource management division and/or their Inventory and Monitoring Network who can help them learn about scientific studies or monitoring programs related to climate change that are taking place in their park, local area, or region. Interpreters also should find a liaison within their park facility management division to keep up to date with climate change mitigation activities in their park, local area, or region. Other regional sources of information include the **Climate Change Response Program** web site, materials developed by Research Learning Centers, and by other governmental agencies, such as the USGS, NOAA, EPA, NASA, USFWS, and Landscape Conservation Cooperatives. See **Appendix IV** at the end of this document for a list of trusted resources for furthering your site-specific research.



Historical and Cultural Literacy and Climate Change

Climate change cannot be fully understood or communicated without an understanding of its human dimensions – it is very much a human story. In addition to knowledge about scientific process and climate science, interpreters need to learn about historical events, timelines, cultural influences, and attitudes that provide the human context for understanding and interpreting climate change.

Climate has shaped the rise and fall of cultures throughout history. Today the reverse is also occurring – the climate that affects humans, is itself affected by humans. Researchers predominantly agree that modern significant human impacts on the global climate began with the Industrial Revolution. The NPS preserves many historical sites that illustrate the human advancements that have created a better, more comfortable way of living for Americans, but have also led to the current changes in climate. When Thomas Edison invented the light bulb or when F.C. Lowell built the factories in Boston, they were done for the benefit of human progress, lacking awareness or concern for the potential long-term consequences to the atmosphere they may cause. Even the establishment of our national parks system was couched in the consumption of resources contributing to our culture of carbon as we encouraged Americans to drive or fly to visit parks. For decades (and even to a certain extent today) success of the national parks was/is measured by visitation numbers. For the vast majority of our visitors, their National Park experiences are defined by how they move through them.

When people think about the effects of climate change in our national parks and other protected areas, they probably think mostly about impacts to natural resources, such as melting glaciers, invasive species, more severe pest outbreaks, and increased forest fires. But climate change is also affecting many of America's great cultural and historic resources protected by the National Park Service. These resources include physical structures like buildings and monuments built with public dollars to commemorate historic people and events; archeological ruins and artifacts that record a 15,000 year history of human occupation on our continent; and iconic sites that record our nation's history. These sites also tell us much about the values that we place on climate change and our role in it, about how past human societies and groups responded to climate change, and about how we arrived at our particular situation of a rapidly changing climate and a growing concern about it.

Questions to ask when considering climate change in a historical or cultural context include:

- How has climate affected different groups of people throughout history?
- What are the human implications of a changing climate for the future?
- How have people responded to a changing climate in the past – and how are we responding today?
- How have human activities and choices impacted climate?
- What aspects of human nature and human events can be linked to climate change?
- What are lessons from the past that help us understand the risks and opportunities of climate change?
- How does climate change connect to other human topics, such as psychology, economics, anthropology, law, philosophy, political science, sociology, business, religion, and environmental studies?

These kinds of questions are useful in identifying interpretive strategies and site connections, but they are also important questions to help audience members grapple with the broader issue of climate change. As with science literacy, helping audience members develop historical literacy about climate change will lead to broader contextual awareness and more informed civic skills in decision-making and problem-solving.

Each NPS site is probably connected in one or more ways to the human story of climate change, and these human connections can be important avenues for helping the public relate to and care about this issue. Obvious cultural connections exist in parks where cultural resources are at risk from a changing climate (sea level rise, increased frequency and severity of storms, increased wild fires, drought, widely fluctuating temperatures, etc.). In other cases, the ability to see our cultural landscapes as places to discuss climate change may require looking beyond our typically "traditional" narratives and into side-paths in the historical record. This may lead to some fascinating and compelling connections and open whole new realms of relevancy related to park resources.

A starter list of possibilities for connecting park resources to the historical and cultural meanings of climate change might include:

- Invention and innovation
- The power of collective action
- The power of individual actions
- Industrialization
- Consumerism
- Transportation
- Travel
- Recreation
- Adapting to change

Case Study: Climate Change Connections in Cultural Parks

Written by John Rudy, Park Ranger / Interpreter, NPS Mather Training Center

The human spirit is an indomitable force, shaping the world around it in amazing and minute ways. The very moment that it looks as if nothing else could possibly come from the human mind, it seems a cascade of shining new thoughts, ideas and strategies begin teeming forth. How many of our cultural parks are dedicated to individuals or groups working together to forge new ideas to leap the greatest hurdles of our age? From the Wesleyan Chapel in New York to Selma to Montgomery in Alabama, from Menlo Park in New Jersey to the Caesar Chavez' home in California, America is crisscrossed with the places where men and women have come together to hash out new ways of tackling America's difficult problems. These shrines to collective action in the face of insurmountable change could act as an inspiration to Americans today who are concerned about climate change. Could Thomas Edison's ever-adaptive mind help us to see that if incremental changes are all it takes to move from a world of darkness into one with moving picture shows and sound recordings, incremental changes could help us solve the climate change catastrophe? Could the Suffragist of the 19th century spark a dialogue on how everyone taking individual action can suddenly spark a movement for change?

Where effects and inspiration do not live within our landscapes, our cultural sites very well might hold clues to the causes of climate change. Pointing to any one particular element of our landscapes and saying, "this is the cause of our problems," might not be exactly possible, but we do know enough about the reasons the climate is shifting to begin finding some of the echoes of its causes within our parks. The 19th century particularly encapsulates an era of vast change in technologies as the industrial revolution swept the globe and fundamentally altered how mankind lives within our environment. The sharp spikes in fuel consumption and carbon dioxide production which began in the mid-1800s and have continued through today seem to correlate with the cataclysmic pace of the warming of our planet. Could sites of the industrial revolution, or the sites where the everyday people who benefitted from the Guilded Age's baubles and trinkets, become places where we talk about consumption and the need for balance? Could a coal stove in an historic parlor be a tangible connection to the warming of the planet just as easily as a species threatened by climactic shift?

And what about us? The Park Service, for nearly a century, has provided for the protection and enjoyment of historic landscapes. Starting in the 1920s and continuing throughout the 20th century, that enjoyment has been largely experienced from the window of an automobile in places like Shenandoah National Park or Colonial National Historical Park. Our auto-parks could offer a brilliant opportunity to discuss how even we, an agency tasked with protecting these unique places, have unwittingly contributed to emissions that now begin to threaten these very resources.

Contextual Awareness – the Big Picture

"When we try to pick out anything by itself, we find it hitched to everything else in the Universe." – John Muir

The natural and cultural resources of national parks are complexly related. It is important for interpreters to recognize the interrelatedness of park resources and how climate change may have cascading and sometimes unpredictable effects throughout entire systems. A holistic perspective is valuable for expanding the relevance of impacts on park resources to a broader context. A holistic approach should recognize the following ideas:

- Parts of a system must be considered in relation to the entire interdependent system (the whole system is more than the sum of the parts).
- A system may consist of hierarchical sub-systems.
- Small events can cause large changes in the system when a threshold is reached.
- Understanding the flow of energy/materials/information through the system is important.
- Feedback loops are important to identify and understand.
- Potential new variables may appear in the system over time
- Dynamic aspects of the system make it important to understand cycles rather than just individual events.

A systems thinking approach is useful in studying both natural and human social systems – the problem of climate change in national parks includes both.

- Natural/cultural systems are very complex and completely interconnected.
- The artificial nature of geographic/political boundaries must be considered – even in NPS sites.
- Numerous agencies/organization/stakeholders share interest and concern.
- There is a need for continued and extensive communication.
- Management policies need to be able to respond to changing conditions.

Interpreters who have a broad understanding of the interrelated natural, historical and cultural aspects of climate change will be better prepared to identify the most compelling and relevant site-specific stories for various audiences.

Local to Global Context

Once the climate change story is grounded in the context of the site, interpreters should consider linking the site-specific story to the larger regional, national or global issue of climate change. While it may not always be appropriate to link to the larger picture, it may be helpful to put the issue of climate change into the larger context and a broader concern or urgency. Interpreters can link what is happening at their sites to other parks and places across the country with similar issues, impacts or stories, or even someplace far away, such as an international sister park, helping visitors connect park-specific stories to other places they already care about or are familiar with.

For example: At park sites in the Rocky Mountains, after explaining how climate change has contributed to forest decimation by pine beetles, interpreters may want to relate this to the death of spruce, pinyon, or juniper forests that visitors may see as they travel throughout the Southwest or to other forest declines occurring in other parts of the world. This may help visitors better understand the scale and broad significance of climate change impacts.

Putting It All Together – Applying Knowledge of Science, History and Culture

Site significance

As an interpreter, a core task in applying your knowledge of climate change is to identify the aspects of your site's significance that are related to this issue. Park resources are set aside and protected by law because of their broad meaning or "significance" to society. This is often articulated in park enabling legislation and the significance statements that accompany park management plans. Climate change is related to site significance either because it impacts or threatens park resources and the values that make them unique, or because park resources and their stories can help us understand the causes and implications of climate change for society. As you identify the ways in which your site's significance connects to climate change, be sure to investigate potential links to park significance statements and interpretive themes from park planning documents. Consider all the potential ways in which climate change has broad societal significance related to your site – in addition to resource impacts, consider impacts to visitor experience, impacts to public perception, and/or in providing access to primary park themes or management goals. What is lost – or gained – at your site because of climate change? What can be understood about climate change because of your site's resources and stories?

Examples of potential stories linking the significance of site resources and climate change

- Glacier National Park – climate change is resulting in glacial recession and loss of alpine meadows
- Joshua Tree National Park – climate change is resulting in loss of habitat suitable for Joshua trees
- Everglades National Park – climate change is resulting in sea level rise and its impacts on wildlife and ecosystems
- Fort Point National Historic Site – the experience of the soldiers stationed here during the civil war can help inspire and teach us today how to effectively address our emotions around climate change
- John Day Fossil Beds National Monument – modern anthropogenic climate change can be understood by comparing rates of change between the fossil record and today
- Montezuma Castle National Monument – climatic change has had consequences for cultures and civilizations of the past
- Thomas Edison National Historic Site – the transformative power of scientific innovation has had both negative and positive ramifications related to climate change
- Antietam National Battlefield – the carbon footprint of the Army of the Potomac can be compared to help us grasp the carbon footprint of modern society
- Rocky Mountain National Park – climate change is resulting in the loss of pine forests due to pine bark beetles and resulting fire dangers

To delve deeper into applying knowledge of science, history and culture see **Appendix V** listed at the end of this document.

References and Resources

It is important to update information for programs, products, etc., at least annually and more often for rapidly changing science topics and climate impacts. In addition to the essential resources already linked throughout this document, other useful tools are listed below.

- Neil Degrasse Tyson video on why it is important to be scientifically literate (2 min)
  http://www.youtube.com/watch?v=5gK2EEwzjPQ

- Climate change – the state of the science video launching the IPCC 5th Assessment report (4min)
  http://vimeo.com/79771046

- IPCC 2013 report illustrated in 19 haikus:
  http://daily.sightline.org/2013/12/16/the-entire-ipcc-report-in-19-illustrated-haiku/

- IPCC survey of scientists: **http://iopscience.iop.org/1748-9326/8/2/024024/article**

- What do pack rats reveal about ancient Chaco architecture or ice archaeology at Glacier?
  http://www.nps.gov/stories/chcupackrat.htm
  http://www.nps.gov/stories/glacicepatch.htm

- NPS Climate Change Talking Points: **http://www.nps.gov/subjects/climatechange/resources.htm**

- Skeptical Science website: **https://www.skepticalscience.com/**

- Real Climate website: **http://www.realclimate.org/**

- International Panel on Climate Change: **http://www.ipcc.ch/**

- U.S. Global Change Research Program: **http://www.globalchange.gov/**

- Physics Today article on climate change communication by Somerville & Hassol
  http://climatecommunication.org/wp-content/uploads/2011/10/Somerville-Hassol-Physics-Today-2011.pdf

- NOAA's *Climate Literacy: The Essential Principles of Climate Sciences* guidebook
  http://oceanservice.noaa.gov/education/literacy.html

- National Academy of Sciences handbook *Climate Change: Evidence, Impacts and Choices*
  http://nas-sites.org/americasclimatechoices/more-resources-on-climate-change/climate-change-lines-of-evidence-booklet/

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APPENDIX I: Science Literacy

1. Science gathers evidence to test explanations of what things are and how things work.
    A. Science attempts to establish common understandings that explain the interactions of nature.
    B. Science assumes nature is essentially orderly and that if objective and verifiable questions are asked, unified explanations, laws, schemes, models, or theories regarding nature are possible.
    C. The work of science is cumulative, builds upon itself, and progresses. Good science changes over time as more research is conducted and critiqued. Good science often results in more questions being asked than were originally answered.
2. Science attempts to gain objective answers to questions through observation, tests, and experiments.
    A. Successful experiments produce measurable evidence.
    B. Experiments, in order to be logical and scientifically meaningful, require the possibility of falsification or the conceivable possibility that the hypothesis can be disproved.
    C. Experiments must be replicable in order for conclusions to be valid.
3. Science organizes conclusions into larger explanations.
    A. Explanations generated by experiments are further tested and validated through efforts to establish their consistency and integration with other explanations.
    B. The more a given explanation fits with other explanations and helps answer other questions the greater validity it attains.
    C. The process of science is self-correcting.
        i. Some explanations gain validity as they are continually tested and evaluated against new explanations.
        ii. Some explanations lose validity, are refined, or are replaced as they are continually tested and evaluated against new explanations.
    D. Theories are the foundations of science. They are widely accepted hypotheses that have not been disproven.
        i. A scientific theory is more than a simple opinion or imagined idea as the common use of the word "theory" might suggest.
        ii. Scientific theories elegantly and logically explain a comprehensive range of evidence.
        iii. Scientific theories are challenged, refined, and validated by competent critics over time. They are the most-tested and most-accepted scientific explanations presently available.
        iv. Scientific theories continue to be refined and adjusted to accommodate testing and logical analysis presented by new scientific explanations.
    E. Scientific work is critiqued and refined through the peer-review process, through publication, and through dissemination of data and methods. This process also corrects for unethical behavior and flawed methods.
4. Uncertainty is a normal part of the scientific process
    A. Scientists often disagree. This is healthy skepticism that helps drive efforts for greater understanding and more useful explanations.
        i. Articulating error and uncertainty is considered strength in scientific work.
            a. Uncertainty is a normal part of prediction, and good science attempts to predict outcomes. Prediction is one way of "testing" when a classic experiment is impractical.
            b. As more work contributes to or critiques existing theory, certainty often increases.
    B. Predictions of complex natural and biological systems inherently have more uncertainty than a small-scale physical study.
        i. Uncertainty can vary over time and space for the same parameter. For example, rainfall may increase over an entire region as predicted by a climate model, but a greater uncertainty exists for conditions at a particular mountaintop location.

APPENDIX II: Resource Impacts of Climate Change in the NPS

This appendix is intended to provide a high level general overview of climate change impacts that will have an impact on national park resources. It should not replace site-specific research that could best be gained through the USGCRP regional reports, NPS Climate Change Talking Points, or consulting with a local resource manager / scientist who has climate science expertise for your site.

1. Context for Specific Impacts: Climate Change through History
   A. Climate has changed in the past, although not very much since modern civilization has evolved; temperature over the last 10,000 years varied less than 1 degree C.
   B. Modern records reveal a number of natural phenomena, some of which are cyclic, that affect global and regional climate for years to decades (e.g., solar output, volcanic activity, and ocean-atmosphere interactions like El Nino/Southern Oscillation; Pacific Decadal, North Atlantic, and Arctic Oscillations).
   C. Paleoclimate studies have demonstrated climate variations over hundreds of thousands of years, most notably the Pleistocene glacial-interglacial cycles that bring massive changes to Earth's system with an average temperature change of about 5 degrees C.
   D. Global temperature began showing a marked warming trend in the mid-1970s to early 1980s that cannot be explained by natural climatic variability; the current strong upward trend can only be explained by anthropogenic warming due to greenhouse gas build-up in the atmosphere.
2. Park Resources – General
   A. Observed Changes
      i. Melting glaciers, cave ice, and permafrost
      ii. Shifting precipitation patterns
      iii. Lowered snowpack and earlier runoff
      iv. Warming water and air temperatures
      v. Increased fire frequency and intensity
      vi. Lengthened summer seasons
   B. Expected Changes
      i. Loss of glaciers and the meltwater they provide to mountains streams
      ii. Lowered streamflow in mid- to late summer with some mountain streams (especially those fed by glaciers) becoming ephemeral
      iii. Higher temperature and lower base flow will stress aquatic organisms and decrease water supply to downstream communities
      iv. Changes in species ranges, with adaptation and migration to more northerly or higher elevation environments
      v. Increased vegetative stress due to late season drying, resulting in increased susceptibility to fire, insects, pathogens, and competition
      vi. Changes in plant phenology, which may no longer be timed to emergence or migration of wildlife
      vii. Rising sea levels with increased storm surges and saltwater intrusion to coastal habitat
      viii. Decreased lake levels
      ix. Shifts in the cultural uses of places by all people: indigenous peoples, visitors, staff
      x. Loss of natural and cultural resources as ecosystems reach a tipping point to sustain them
3. Temperature and Precipitation
   A. Observed Changes
      i. Warming temperature: Virtually all locations in the U.S. have warmed by ~ 0.6 degrees C over the last century; parks in the West have warmed more than the national average. Parks at northern latitudes and high elevations have warmed about twice as much as the average.

ii. Precipitation changes: The West is experiencing less snow and more rain in winter, lower snowpack to feed streamflow in summer, and an advance of spring runoff by about two weeks.

B. Expected Changes

i. Temperature is expected to increase in all parks.

ii. Drought may occur more frequently in some parks (Great Plains, Desert Southwest).

iii. Some parks may experience more storms and flooding (Pacific Northwest; marine coastlines).

iv. Expect changes to all seasons (e.g., warmer winters and summers, drying in summer and extended into the fall in areas prone to drought, more variable springs, possible winter flooding, etc.).

4. Glaciers, Snowpack, and Permafrost

A. Glaciers and icefields are decreasing rapidly in area, thickness, and volume pretty much across the planet; some parks may experience a complete loss of glaciers before the end of the century.

B. Snow fields and winter snowpacks will decrease in size and persist for shorter seasons over the coming decades, changing the timing and quantities of runoff and streamflow rates.

C. Changes mean that archeological sites and other resources previously capped by glaciers and icefields will be exposed such that fragile artifacts or organic materials will be threatened and sites made more obvious to looters.

5. Watersheds/aquatic systems

A. Wetlands may receive more or less water depending on their location, but many may become drier overall as evapotranspiration due to increased temperature is expected to exceed any net gain in precipitation.

B. Earlier runoff, warmer water, evaporative stress, and reduced summer streamflow are expected to stress many aquatic organisms.

C. Species that require cold water (such as many species of trout) or those near the edge of their geographical ranges are at the greatest risk and will probably need to migrate or be relocated if they are to survive.

D. Aquatic chemistry and ecology may change drastically in some locations, with exotic invasives able to outcompete natives under stressed environmental conditions.

E. The status of submerged or coastal cultural resources may change. Resources may face destruction, loss, or require relocation.

F. The look and feel of cultural landscapes will alter as watercourses do (e.g., canals at Chesapeake and Ohio Canal NHP or Cuyahoga Valley NP, rivers at Harpers Ferry NHP or Rio Grande WSR).

G. Reduced water supply is a major concern with a warming climate, especially in the West where runoff from winter snowpack is the primary source of fresh water.

6. Air Quality

A. Airborne contaminants have both warming and cooling effects on climate.

B. Tropospheric ozone (along with carbon dioxide, methane, nitrous oxide, and CFCs) is a greenhouse gas that absorbs outgoing radiation and heats the atmosphere.

C. Most aerosols (i.e., fine liquid and solid particles including sulfates, organic carbon, biomass burning, and soil dust) cool the planet by scattering incoming radiation. Some aerosols (black carbon or "soot"), however, contribute to global warming by absorbing radiation. In addition, when soot deposits on snow, glaciers, or ice sheets, it darkens the surface, strongly increasing warming and melting.

D. Aerosols also affect the properties of cloud droplets, increasing reflectiveness and causing cooling, but there is large uncertainty regarding this effect, changing precipitation patterns and causing drought in some areas and more intense storms in others.

E. Air pollution is expected to increase in both severity (high concentrations) and duration (length of pollution episodes) due to increases in emissions and changes in climate, particularly warmer temperatures and changes in weather patterns.

F. Air quality issues will impact the composition of historic fabric and treatments thereof, plant matter in cultural landscapes, and other cultural resources.

7. Vegetation
    A. Vegetation is generally expected to come under adaptive pressure to migrate northward and to higher elevations as temperature warms and the growing season lengthens.
    B. Invasion of subalpine meadows by tree seedlings may be enhanced due to lack of snowpack near treeline. Much depends on whether the surrounding environment is suitable for seedlings to become established and if plant physiological processes can keep pace with the rate of environmental change (long-lived species such as giant sequoias may be in trouble).
    C. Rapid change and disturbance such as fire may favor establishment of opportunistic invaders over expansion of native species.
    D. Phenologic changes are expected to shift toward earlier flowering; some of these shifts have already been observed which may cause a mis-match of timing for species that depend on them for survival.
    E. Forests may experience massive, sudden die-back as trees become drought-stressed and more susceptible to pests, pathogens, and/or fire (as has been observed in the pinyon-juniper and pine forests of the Western U.S. and Western Canada).
    F. Indigenous peoples may increasingly encounter difficulty in accessing and harvesting plants for traditional uses.
    G. A longer growing season, with consequently more opportunity for invasive exotics to grow and spread, will affect the integrity and fabric of cultural resources, such as archeological sites or historic structures, as well as the look and feel of the cultural landscape.
    H. Changing climatic zones may turn over the historically accurate vegetation of a cultural landscape or historic scene. Parks may need to choose historically inaccurate plantings to be sustainable within the context of climatic changes.
8. Wildlife
    A. Mobile, omnivorous generalists may be able to adapt to a variety of conditions. However, species with narrow ranges and tolerances will be tied closely to the fate of their habitat.
    B. Lower elevation species may migrate upslope if possible.
    C. Some high-elevation species, such as pikas, may run out of suitable habitat and become locally or regionally extinct.
    D. Rare or unusual species, such as many orchids, may become more vulnerable if their habitats are disturbed by migrating wildlife. Species currently living in relatively isolated habitats that have little opportunity to migrate to other locations are most at risk. Examples include cold-temperature suites of species that currently exist at the edge of their range or tolerance (e.g., arctic plants such as thimbleberry, arctic crowberry, Lake Huron tansy, and Pitcher's thistle at Picture Rocks NL; ice-age relicts such as cedar-hemlock forests at Glacier NP) and species already at the limit of tolerance such as those living near the edge of an ecotone.
    E. Indigenous peoples may increasingly encounter difficulty in accessing and harvesting wildlife for traditional uses. This includes any park species or community already at risk of extinction, especially those living in high-risk habitats such as cold aquatic, high-elevation, or high-latitude environments or transition zones such as shorelines and estuaries.
9. Disturbance of Natural Systems
    A. There is evidence that the longer and more severe fire seasons experienced in the West since around the mid-1980s are related to warmer temperatures and less snow.
    B. Late-winter flooding in the Pacific Northwest is also consistent with a shift in winter precipitation from less snow and more rain.
    C. It is fairly clear that storm surges near coastal areas will reach farther inland, and thus do more damage, as sea levels rise; there is some evidence that hurricanes might be less frequent but more intense under global warming conditions.

D. In the short term, snow avalanches may be more common in late winter and spring if the area experiences mid-winter melting and rain-on-snow conditions; in the long term, snow avalanches will probably decrease in frequency if snowpack continues to diminish.

E. Debris flows may become more common if more rain is received in storm events.

F. Environmental stress from rapid climate change will likely favor more aggressive species (often non-native invaders) over native species in many systems.

G. Changes to natural systems will affect “preserve-in-place” treatment strategies for cultural resources as acid rain, floods, invasive species, and other episodes impact them.

10. Cultural Resources

A. Archeological resources will be affected by natural processes, geological and geographical shifts, and changes to the locations and health of plant and animal species. Exposure to the elements, disruption to context, and loss of integrity are anticipated.

B. Historic structures (including standing buildings, bridges, and roads) may be stressed as temperature and humidity changes affect both their fabrics and the effectiveness of treatments. Weather cycles, longer growing seasons, invasive plant and insect species, and shoreline and water table changes are among the potential impacts.

C. Ethnographic resources may shift in their locations, which affects the ability of indigenous peoples to use places or resources for cultural purposes. If species become extinct, cultural practices will change or be lost.

D. Cultural landscapes will change in their overall look and feel as vegetation and wildlife populations change, as the contours of geological and geographic features shift, and as visual cues such as historic structures are destroyed or moved.

E. Museum collections will likely increase due to mitigation measures ahead of climate change impacts to archeological sites, ethnographic resources, and historic structures.

11. Coastlines and Sea Level Variability

A. Lake levels of the Great Lakes are projected to decline, exposing new land areas, changing accessibility for boats, and potentially draining coastal wetlands.

B. Storm surges, hurricanes, and sea level rise threaten natural and cultural resources as well as park infrastructure.

C. Marine coastal zones will be inundated with saltwater as sea level rises, resulting in potential loss of intertidal resources and an increase in the subtidal area.

D. Beaches, trails, roads, and other access points and recreation areas will likely be disturbed or lost.

E. Heat stress and related diseases will negatively impact corals and other tropical marine organisms; coral bleaching has already been observed during very warm years.

F. Long-term effects of ocean acidification due to carbon dioxide absorption are potentially catastrophic for marine life.

12. Facilities and Infrastructure

A. Non-historic buildings, such as visitor centers, maintenance yards, employee housing, and administrative buildings, will be affected by climate changes as weather patterns and ecosystem shifts occur.

B. Parks may require new equipment as circumstances dictate (e.g., snow tires and chains when none were required before, which will impact roads and vehicle maintenance).

C. Roads may heave during freezes, wash out, or experience other problems. Dirt roads, asphalt, gravel, or other materials will be affected differently.

D. Campgrounds, concession facilities, comfort stations, and visitor centers may experience flooding, fallen trees, loss of power from storms and hurricanes, or loss of buildings due to fire or may need to be moved.

E. Activities to mitigate NPS operational carbon footprint includes alternative fuels, hybrid or electric vehicles, carpooling or alternative transportation programs, fillable water stations and prohibition of selling disposable bottles or food containers, purchasing energy-efficient supplies, and solar and wind power, etc.

13. Recreation and Tourism

A. Park managers are concerned that changes to some of their most significant resources, such as the glaciers at Glacier NP, joshua trees at Joshua Tree NP, or boreal forests at Voyageurs NP will alter the long-term planning and management of their parks, as well as the visitor experience.

B. Longer summer seasons may allow more people to experience parks but will also bring pressure for added personnel and maintenance of facilities.

C. For coastal parks, sea level rise may have major impacts on tourism-based economies if land areas are inundated with saltwater or submerged.

D. Interpretive programs may change as parks adjust the stories they tell as primary resources are affected (e.g., the Portage Glacier Visitor Center just outside of Anchorage lost their primary resource and as a result the USFS undertook a costly rehab of the entire visitor center and completely changed their interpretive themes).

E. Recreational opportunities may be affected if managers need to limit access to park resources in order to minimize additional impacts to stressed systems or maintain a safe environment for visitors. (e.g., key bear-denning habitat areas closed to visitor use at critical times).

APPENDIX III: Awareness of Monitoring Approaches

1. Types of information resource managers will research or gather
   A. High-risk species: Identify which species are most vulnerable to temperature and precipitation changes and get baseline surveys completed; identify whether any parks are currently one of the few remaining places for rare species (including but not limited to threatened and endangered species).
   B. High-risk cultural resources: Identify which resources are most vulnerable to temperature and precipitation changes, as well as the effects of those changes such as sea level rise, and ensure that baseline surveys are complete.
   C. Create archives of photography, GPS, and other data to chronicle existing (and previous if possible) conditions for future reference; include oral histories.
   D. Establish or contribute to existing seed banks to preserve seeds of plants unique to park systems.
   E. Describe for posterity those resources, and relationships among resources, that will ultimately be lost.
2. Types of approaches to monitoring for climate change in national parks and protected areas
   A. Where possible, park vital signs monitoring and reporting frameworks should include hydrologic and water quality measures; ensure basic I&M network monitoring of climate and indicators (e.g., glaciers, spring snowpack, streamflow, lake levels, maximum temperature, minimum temperature, precipitation, streamflow, vegetation phenology).
   B. Alpine vegetation and biogeochemistry to forecast, monitor, and interpret changes in the alpine zone (e.g., pikas, wildflowers, butterflies).
   C. High-risk species: Monitor changes in sensitive species whose habitats are threatened under any climate change scenario; use information to determine management actions (sensitive species that are most susceptible to small changes to the ecosystem may be the rare species in our parks that we are most concerned about and also may be the species most difficult to save).
   D. Transitional habitats near the edge of an ecotone may be very sensitive to even minor shifts in temp and precipitation. (e.g., alpine treeline, shorelines, estuaries).
   E. Monitor for threshold shifts which are rapid, cascading changes that affect—and often degrade—entire systems. Park managers should work closely with scientists to understand the potential for thresholds shift responses to climate change and develop adaptation strategies for dealing with them.
   F. Track impacts to cultural resources to understand the encroachment of climate change impacts and how that could affect park operations.

APPENDIX IV: Trusted Resources for Further Research

1. Become familiar with current research in the park or region
   A. Climate science summaries are under development for all NPS units. Approximately 100 parks have been completed and the rest are scheduled to be done by 2016.
   B. A number of NPS Research Learning Centers (RLC) have begun to research and educate about climate change. Contact your nearest RLC for opportunities to collaborate. http://www.nature.nps.gov/rlc/
   C. NPS Inventory and monitoring (I&M) networks; 32 networks across the country monitor vital signs for climate impacts and indicators for the resources represented within their specific network. http://science.nature.nps.gov/im/networks.cfm
   D. The U.S. Global Change Research Program produces up-to-date regional climate change assessments for 8 regions and develops a brief 2-page overview for each.
   E. DOI Landscape Conservation Cooperatives (LCC) are a collaboration among federal agencies and partner organizations to apply management decisions across landscapes. Your local LCC may be a great resource for seeking out science expertise. http://www.fws.gov/landscape-conservation/lcc.html
   F. DOI Climate Science Centers (CSC) are a collaboration among climate scientists in federal agencies, universities and partner organizations and they aim to provide up-to-date climate science that can inform management decisions. http://www.doi.gov/csc/index.cfm
2. Partner Organizations websites about climate change
   A. The EPA website has a good basic overview of climate science, impacts by region, adaptation actions for land managers, and action we can take to mitigate our carbon footprint. http://www.epa.gov/climatechange/
   B. The NASA Earth to Sky website has a variety of communication and science resources as well as a listserv for email updates. http://earthtosky.org/
   C. The U.S. Forest Service has a robust website on how they are addressing climate change within our national forests. http://www.fs.fed.us/ccrc/
   D. The US Fish & Wildlife Service also has many regional and site-specific resources related to climate change. http://www.fws.gov/home/climatechange/
   E. The USGS website hosts the latest reports and scientific studies related to land management and protected areas and climate change. http://www.usgs.gov/climate_landuse/
   F. Parks located in coastal areas may find applicable resources on NOAA's website. http://www.noaa.gov/climate.html
3. Other websites and databases
   A. NPS Integrated Resource Management Application (IRMA) portal contains peer-reviewed reports and other data searchable by the term climate change. https://irma.nps.gov/App/Portal/Home
   B. National Archeological Database and Reports is also a searchable database for climate change reports related to cultural resources. http://cast.uark.edu/other/nps/nadb/

APPENDIX V: Applying Knowledge of Science, History, and Culture

1. Synthesize the scientific knowledge into non-technical language interpreters can use.
   A. Translation of complex data: Part of the challenge of interpreting climate change involves sifting through complex data sets from multiple disciplines that may not come already synthesized or translated into plain English. The task for the interpreter is to translate complex data sets into language that is accessible to a broad audience and also to know when using complex data or professional terms is appropriate and effective.
2. Each data set comes with its own language, or professional jargon, that may inhibit the ability of the interpreter to communicate the meanings of the data in an effective way.
   A. What words and phrases are unique to climate change science and/or to the professional study of resources in the park/region? Do terms in one field cross over into another field, but have different meanings or implications or shorthands (e.g., lithics in geology vs. archeology)? (Public language or terminology) [Here: The public may use language to describe particular issues or situations that is not correct within the context of climate change. What terms are at issue?]
   B. What words and phrases are key to climate change literacy but are not self-evident in their meaning? What words themselves give too few—or too simplified—contextual clues (e.g., global warming)? How can they be translated into plain English without falling into colloquial traps or inappropriate analogies?
   C. When is it appropriate to use jargon? When is it best to use plain English? What are the effects of each in an interpretive product or on a particular audience? What techniques can interpreters use to weave jargon and plain English into interpretive products?
3. Complex data can come in narrative or graphic forms. Interpreters should become familiar with analyzing data in various formats.
   A. Learn to distill detailed data communicated by graphics into a set of main points or seek assistance from resource managers.
   B. Identify a scientist's purpose for including the graphic and the ways that it clarifies any scientific discussion accompanying it.
   C. Identify when data in narrative form is better communicated through graphics. Interpreters should be versed in the use of multiple techniques to help explain the science.
4. Understand where and how to integrate resource data and synthesize it to yield the most relevant meanings.
   A. Part of science literacy involves understanding where and how to integrate data from different data sets, especially across resource types. The resulting synthesis can reveal insights on the significance of climate change, and its different meanings, from different perspectives.
   B. Interpreters should be able to recognize the science content that pertains to their parks in order to make park-specific programs and messages.
   C. Interpreters should work with resource management to develop effective and accurate props, messages, and programs.
   D. Interpreters should distill what is relevant to the park.
   E. Interpreters should share/start the conversation in a place that will further the visitor's understanding.
   F. Interpreters should assess how much of their information "should be" shared. A good rule is the "Iceberg Rule": the 10 percent above the water is what you share; the 90 percent below the water is the knowledge base you have to fall back on when a visitor asks an in-depth question.
   G. Interpreters should identify how data from one set of resources may enhance understanding of another resource type, question, or problem.
   H. Interpreters should identify when data from different sources or formats is in conflict and how to resolve those conflicts.
   I. Interpreters should pull out the "so what" from data to construct resource meanings. The relevance should connect to individual resource types, resources in tandem, the park unit, region, etc.

J. Interpreters should convey why science literacy is essential to climate change issues and why the public must be science literate to engage civically.

K. Interpreters should listen to the audience's questions, comments, and feedback to identify things that are working and areas where the audience is not resonating with the content. Interpreters should apply adaptive interpretation to adjust content to better engage and enlighten the audience.

5. Understand where and how to integrate positive messages and calls to action for stewardship of resources and sustainability.

   A. Provide relevant messages that are park specific and audience appropriate.

   B. Provide messages of hope—hope through action and participation.

   C. Give audiences ways they can be involved and help with the solution